

FAA-STD-019e
December 22, 2005

ATTACHMENT D



DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION STANDARD

LIGHTNING AND SURGE PROTECTION,
GROUNDING, BONDING AND SHIELDING
REQUIREMENTS FOR FACILITIES AND
ELECTRONIC EQUIPMENT

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FOREWORD

All construction of Federal Aviation Administration (FAA) operational facilities and the electronic equipment installed therein shall conform to this standard. This document defines minimum requirements for all FAA facilities. When the specific needs of a facility exceed these minimum requirements, the facility shall be designed and installed to meet these specific needs. These needs are influenced by the equipment to be installed at the site, the configuration of the structures and location of the equipment, and by the physical environment present at the location.

The requirements contained in this document reflect investigation and resolution of malfunctions and failures experienced at field locations. The requirements thus are considered the minimum necessary to harden sites sufficiently for the FAA missions – to prevent delay or loss of service, to minimize or preclude outages, and to enhance personnel safety. Further, the requirements in the document have been coordinated with industry standards, and in some cases exceed industry standards where necessary to meet the FAA missions.

In this document the use of “shall” or verbs such as “construct”, “weld”, “connect”, etc indicates a requirement necessitating mandatory compliance. In cases when implementation of certain requirements is not technically feasible, a National Airspace System (NAS) Change Proposal (NCP) must be submitted with adequate justification and technical documentation and approved by the NAS Configuration Control Board (CCB) before a deviation is permitted.

This document is organized in accordance with MIL-STD-962D.

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1 SCOPE

1.1 Scope

This document mandates standard lightning protection, transient protection, grounding, bonding and shielding configurations and procedures and control of electrostatic discharge (ESD) for new facilities, modifications and upgrades to existing facilities, new equipment installations, and new electronic equipment used in the National Airspace Systems (NAS). It provides requirements for the design, construction, modification or evaluation of facilities and equipment. (It is recommended that the OPR of this document be contacted to obtain technical guidance on the applicability of the requirements to modifications, upgrades and new equipment installations in existing facilities.)

This document is not mandatory for programs that have been funded prior to the issue date of this document, nor is it mandatory for construction contracts associated with programs funded prior to the issue of the document. Application of this document is at the discretion of the user for programs that have been funded prior to the issue of the document. The Office of Primary Responsibility (OPR) can mandate the use of this document for programs started before the issue date of this document, if funding is provided.

The interface between contractor owned equipment or electronic equipment not used for operational purposes (administrative local area network (LAN), administrative telephone, etc.) and the operational facility shall be in accordance with this document.

1.2 Purpose

The requirements of this standard provide a systematic approach to minimize electrical hazards to personnel, electromagnetic interference and damage to facilities and electronic equipment from lightning, transients, ESD, and power faults.

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2 APPLICABLE DOCUMENTS

2.1 Government Documents

Due to the continuous updating of Government documents, the Contracting Officer and/or the Implementation Engineer must specify the version current at contract award or project design. These documents form a part of this standard and are applicable to the extent specified elsewhere in this document. If conflicts occur between these documents and the contents of this standard, the contents of this standard provide the superseding requirements.

FAA Specifications

FAA-C-1217	Electrical Work, Interior
FAA-G-2100	Electronic Equipment, General Requirements
NAS-SS-1000	Functional and Performance Requirements for the National Airspace Air Traffic Control Element

FAA Orders

Order 6950.19	Practices and Procedures for Lightning Protection, Grounding, Bonding and Shielding Implementation
Order 6950.20	Fundamental Considerations of Lightning Protection, Grounding, Bonding and Shielding

(Copies of these specifications, standards, orders, and other applicable FAA documents may be obtained from the Contracting Officer issuing the invitation-for-bids or request-for-proposals. Requests should fully identify material desired, i.e. specification, standard, amendment, drawing numbers and dates. Requests should cite the invitation-for-bids, request-for-proposals, the contract involved, or other use to be made of the requested material.)

Military Documents

MIL-HDBK-232	Revision A Red/Black Engineering-Installation Guidelines
MIL-HDBK-237	Electromagnetic Compatibility Management Guide for Platforms, Systems and Equipment
MIL-HDBK-253	Guidance for the Design and Test of Systems Protected Against the Effects of Electromagnetic Energy
DOD/MIL-HDBK-263	Electrostatic Discharge Control Handbook
DOD-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
MIL-HDBK-419	Grounding, Bonding, and Shielding for Electronic Equipment and Facilities
MIL-PRF-87893	Performance Specification, Workstations, Electrostatic Discharge Control

MIL-W-87893	Military Specification, Workstations, Electrostatic Discharge (ESD) Control
MIL-STD-461	The Control of Electromagnetic Interference Emissions and Susceptibility
MIL-STD-889	Dissimilar Metals
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)
NACSIM 5203	Guidelines for Facility Design and Red/Black Installation (Confidential Document)

Single copies of Military specifications, standards, and handbooks may be requested by mail or telephone from Document Automation and Production Service Customer Service, Standardization Documents Order Desk, 700 Robbins Avenue, Building 4D Philadelphia, PA 19111-5094 or via dodssp.daps.dla.mil. Not more than five items may be ordered on a single request; the Invitation for Bid or Contract Number should be cited where applicable. Only latest revisions (complete with latest amendments) are available; slash sheets must be individually requested. Request all items by document number.

2.2 Non-Government Documents

Due to the continuous updating of Non-Government documents, the Contracting Officer and/or the Implementation Engineer must specify the version current at contract award or project design unless a specific version is called out in the requirements of this standard. These documents form a part of this standard and are applicable to the extent specified herein. While this standard may exceed the requirements of the following documents, Nationally required practices shall always be performed as a minimum.

Electronic Industries Alliance (EIA)

EIA Standard EIA-625	Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices
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Requests for copies of EIA Standards should be addressed to Electronic Industries Alliance, Corporate Engineering Department, 2500 Wilson Boulevard, Arlington, VA 22201 or telephone 703 907-7500. www.eia.org

National Fire Protection Association (NFPA)

NFPA 70	National Electrical Code (NEC)
NFPA 77	Static Electricity
NFPA 780	Standard for the Installation of Lightning Protection Systems

Requests for copies of NFPA documents should be addressed to the National Fire Protection Association, One Batterymarch Park, Quincy MA 02269. www.nfpa.org

Underwriters Laboratories, Inc. (UL)

UL 96	Lightning Protection Components
UL 96A	Installation Requirements for Lightning Protection Systems
UL 779 (ANSI-A148.1)	Electrically Conductive Floorings
UL 1449	Transient Voltage Surge Suppressors

Requests for copies of UL documents should be addressed to Global Engineering Documents, 1500 Inverness Way, East Englewood, CO 80112. Telephone 303 397-7945, 800 854-7179. www.ul.com

Institute of Electrical and Electronic Engineers (IEEE)

ANSI/IEEE C62.41	Recommended Practice on Surge Voltages in Low Voltage AC Power Circuits
ANSI/IEEE C62.45	IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits
ANSI/IEEE 1100	Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)

Requests for copies of IEEE documents should be addressed to Institute of Electrical and Electronic Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-9916. www.ieee.org

Electrostatic Discharge (ESD) Association Documents

ESD ADV53.1	ESD Protective Workstations
ANSI/ESD S4.1	Worksurfaces – Resistance Measurements
ANSI/ESD S7.1	Floor Materials, Characterization of Materials
ANSI/ESD S8.1	Symbols – ESD Awareness
ANSI/ESD S11.11	Surface Resistance Measurement of Static Dissipative Planar Materials
ANSI/ESD S20.20	Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment
ANSI/ESD STM5.1	Sensitivity Testing, Human Body Model (HBM), Component Level
ANSI/ESD STM12.1	Seating - Resistive Measurement
ESD TR20.20	Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment – Handbook

Requests for copies of ESD Association documents should be addressed to the ESD Association, 7900 Turin Road, Bldg 3, Suite 2, Rome, NY 13440-2069. Telephone 315 339-6937. www.esda.org

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3 DEFINITIONS

3.1 Access Well

A covered opening in the earth using concrete, clay pipe or other wall material to provide access to an EES connection.

3.2 Air Terminal

That component of a lightning protection system specifically designed to accept lightning strikes.

3.3 Armored Cable

Power, signal, control or data cable having an overall armor or covering constructed of ferrous (steel) material that provides both structural protection and electromagnetic shielding for direct buried cables.

3.4 Arrester

Components, devices or circuits used to attenuate, suppress, limit, and/or divert adverse electrical (surge and transient) energy. The terms arrester, suppressor and protector are used interchangeably except that the term arrester is used herein for components, devices and circuits at the service disconnecting means.

3.5 Bond

The electrical connection between two metallic surfaces used to provide a low resistance path between them.

3.6 Bond, Direct

An electrical connection utilizing continuous metal-to-metal contact between the members being joined.

3.7 Bond, Indirect

An electrical connection employing an intermediate electrical conductor between the bonded members.

3.8 Bonding

The joining of metallic parts to form an electrically conductive path to assure electrical continuity and the capacity to conduct current imposed between the metallic parts.

3.9 Bonding Jumper

A conductor installed to assure electrical conductivity between metal parts required to be electrically connected.

3.10 Branch Circuit

The circuit conductors between the final overcurrent device protecting the circuit and the load served.

3.11 Building

The fixed or transportable structure which provides environmental protection.

3.12 Bulkhead Plate

A metallic plate located where conduits, conductor, waveguides etc first enter the facility. The bulkhead plate provides a central point for the grounding of conduits, conductors and waveguides entering the facility or structure.

3.13 Cabinet

An enclosure designed either for surface mounting or flush mounting and is provided with a frame, mat, or trim in which a swinging door or doors are or can be hung.

3.14 Cable

A fabricated assembly of one or more conductors in a single outer insulation. Types include axial, armored and shielded.

3.14.1 Cable, AC (not the same as armored (DEB) cable)

Type AC cable is a fabricated assembly of insulated conductors in a flexible metallic enclosure.

3.14.2 Cable, Armored Direct Earth Burial (DEB)

Cable with a ferrous shield designed to provide both physical and electromagnetic protection to the conductors.

3.14.3 Cable, Axial

Cable where all conductors are oriented on a single axis. Examples include coaxial, biaxial, and triaxial cables

3.14.4 Cable, Shielded

Cable with a metalized or braid shield to improve resistance to electromagnetic interference (EMI).

3.15 Case

A protective housing for a unit or piece of electrical or electronic equipment.

3.16 Catenary Wire

A catenary lightning protection system consisting of one or more overhead ground wires and supporting masts.

3.17 Chassis

The metal structure that supports the electrical or electronic components which make up the unit or system.

3.18 Clamp Voltage

Clamp voltage is the voltage that appears across the SPD terminals when the suppressor is conducting a surge or transient current.

3.19 Conductor, Bare

An electrical conductor that has no covering or electrical insulation.

3.20 Conductor, Insulated

An electrical conductor encased within material of composition and thickness recognized by the NEC as electrical insulation.

3.21 Conductor, Lightning Bonding (Secondary)

An electrical conductor used to bond a metal object, within the zone of protection and subject to currents induced by lightning strikes, to the lightning protection system.

3.22 Conductor, Lightning Down

The down conductor serves as the path to the earth grounding system from the roof system of air terminals and roof conductors or from an overhead ground wire.

3.23 Conductor, Lightning Main

The main conductors are the conductors intended to carry lightning currents between air terminals and ground terminations. These can be the roof conductors interconnecting the air terminals on the roof, the conductor to connect a metal object on or above roof level that is subject to a direct lightning strike to the lightning protection system, or the down conductor.

3.24 Conductor, Lightning Roof

Roof conductors interconnecting all air terminals to form a two-way path to ground from the base of each air terminal.

3.25 Crowbar

The term “crowbar” refers to a method of shorting a surge, voltage, or current using surge protective devices.

3.26 Earth Electrode System (EES)

A network of electrically interconnected rods, plates, mats, piping, incidental electrodes (metallic tanks, etc.) or grids installed below grade to establish a low resistance contact with earth.

3.27 Electromagnetic Interference (EMI)

Any emitted, radiated, conducted or induced voltage which degrades, obstructs, or interrupts the desired performance of electronic equipment.

3.28 Electronic Multipoint Ground System

An electrically continuous network consisting of interconnected ground plates, equipment racks, cabinets, conduit junction boxes, raceways, duct work, pipes, copper grid system, building steel, and other non-current-carrying metal elements. It includes conductors, jumpers and straps that connect individual items of electronic equipment to the SRP or MPG system.

3.29 Electronic Single Point Ground (SPG) System

An SPG signal reference network provides a single point reference in the facility for equipment that requires single point grounding. It consists of conductors, plates and equipment terminals, all of which are isolated from any other grounding system except at the main ground plate.

3.30 Enclosed Ferrous Cable Tray

A cable tray with steel sides and bottom with a steel cover or lid. This tray may have small holes and gaps.

3.31 Equipment Areas

Areas that contain electronic equipment used to support NAS operation. These include electronic equipment rooms, TELCO rooms, VORs, Radars etc.

3.32 Equipment Grounding Conductor

The conductor with the phase and neutral conductors used to connect non-current-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or to the grounding electrode conductors at the main service disconnecting means or at the point of origin (X_o bond) of a separately derived system.

3.33 Equipment

A general term including materials, fittings, devices, appliances, fixtures, apparatus, machines, etc, used as a part of, or in connection with, an electrical installation.

3.34 Facility Ground System

Consists of the complete ground system at a facility including the EES , SRP or MPG system, electronic single point ground system (SPG), equipment grounding conductors, grounding electrode conductor(s), and lightning protection system.

3.35 Faraday Cage

A closed conducting surface, such as wire mesh, completely surrounding an object or person so as to protect from impinging electromagnetic waves.

3.36 Feeder

All circuit conductors between the service equipment or the source of a separately derived system and the final branch circuit overcurrent device.

3.37 Ferrous Conduit

Material composed of and/or containing iron. Rigid Galvanized Steel Conduit (RGS) thick walled threaded conduit (NEC Rigid Metal Conduit (RMC)). For the purpose of this document, conduits not adequate for magnetic shielding include Electrical Metallic Tubing (EMT), Intermediate Metal Conduit (IMC) and conduits made from silicon bronze and stainless steel.

3.38 Fitting, High Compression

See "Pressure Connector".

3.39 Ground

A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

3.40 Grounded Conductor

A system or circuit conductor that is intentionally grounded at the service disconnecting means

or at the source of a separately derived system. This grounded conductor is the neutral conductor for the power system.

3.41 Grounded

Connected to earth through a connection of sufficiently low impedance and having sufficient current carrying capacity so that fault current which occurs cannot build up to voltages dangerous to personnel.

3.42 Grounding Conductor

A conductor used to connect equipment or the grounded circuit of a wiring system to the grounding electrode system. (In this standard, grounding conductors not related to or not used as part of NEC required electrical system grounding, are used for the electronic equipment grounding system).

3.43 Grounding Electrode

Copper rod, plate or wire embedded in the ground for the specific purpose of dissipating electric energy to the earth.

3.44 Grounding Electrode Conductor

The conductor used to connect the grounding electrode to the equipment grounding conductor and/or to the grounded (neutral) conductor of the facility at the service disconnecting means or at the source of a separately derived system.

3.45 High frequency

All electrical signals at frequencies greater than 100 kilohertz (kHz), and pulse and digital signals with rise and fall times of less than 10 μ s are classified as high frequency signals.

3.46 Horizontal Transitions

Architectural term used to describe horizontal elements in a vertical structure (floors stair landings, etc.).

3.47 Jordan Dissipation Plate Design

Based on original design from W. Jordan FAA OKC.

3.48 Landline

Any conductor, line or cable installed externally above or below grade to interconnect electronic equipment in different facility structures or to interconnect externally mounted electronic equipment.

3.49 Line Replaceable Unit

Hardware elements whose design enables removal, replacement and checkout by organizational maintenance.

3.50 Low Frequency

Includes all voltages and currents, whether signal, control, or power, up to and including 100 kHz. Pulse and digital signals with rise and fall times of 10 μ s or greater are considered to be low frequency signals.

3.51 Main Service Disconnect

Main Service Disconnect is a switch, fused switch or circuit breaker that disconnects main service AC power (generally utility power) from a facility. Also referred to as Service Disconnecting Means (SDM).

3.52 National Electrical Code

A standard containing provisions that govern the use of electrical wire, cable, equipment and fixtures installed in buildings.

3.53 Operational Areas

Areas used to provide NAS support such as IFR rooms, ARTCC control rooms, ATCT tower cabs and operations control centers.

3.54 OPR

OPR is an acronym for Office of Primary Responsibility. The OPR is assigned to maintain and interpret this standard.

3.55 Overshoot Voltage

The fast rising voltage that appears across transient suppressor terminals before the suppressor turns on (conducts current) and clamps the input voltage to a specified level.

3.56 Pressure Connector

For purpose of this document, "FAA approved pressure connectors" shall be those that use hydraulically crimped terminations to effect closure.

3.57 Rack

A frame in which one or more equipment units are mounted.

3.58 Reference Plane or Point, Electronic Signal (Signal Ground)

The conductive terminal, wire, bus, plane, or network which serves as the relative zero potential for all associated electronic signals.

3.59 Rigid Metal Conduit (RMC)

A threadable raceway of circular cross section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed with its integral or associated coupling and appropriate fittings.

3.60 RGS

See Ferrous Conduit.

3.61 Shield

A housing, shield, or cover which substantially reduces the coupling of electric and magnetic fields into or out of circuits or prevents accidental contact of objects or persons with parts or components operating at hazardous voltage levels.

3.62 Signal

Any electromagnetic transmission of information or control function. A signal can be analog, digital data or a control function such as a relay closure.

3.63 Standard Version

The applicable version of the standard is that issue in effect on the date of a contract signing.

3.64 Structure

Any fixed or transportable building, shelter, tower, or mast that is intended to house electrical or electronic equipment or otherwise support or function as an integral element of the air traffic control system.

3.65 Surge

An overvoltage or overcurrent of short duration occurring on a power line.

3.66 Susceptibility Level

The electronic equipment susceptibility level is the least of the damage, degradation, or upset levels considering all electronic components potentially affected by conducted or radiated transients.

3.67 Transient

An overvoltage or overcurrent pulse on a power, signal, control, or data line.

3.68 Transient Suppressor

Components, devices or circuits designed for the purpose of attenuating, absorbing and suppressing conducted transient and surge energy to protect facility equipment.

3.69 Turn-on Voltage

The voltage required across transient suppressor terminals to cause the suppressor to conduct current.

3.70 Zone of Protection

The zone of protection is that space adjacent to a lightning protection system that has a reduced probability of receiving a direct lightning strike.

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4 GENERAL REQUIREMENTS

4.1 Requirements Common to Both Facilities and Equipment

This section provides requirements that are established to ensure the proper operation of FAA facilities and equipment. The use of the term “facilities” in this document can differ from the manner in which it is frequently used in other FAA documents. In this document, physical proximity of equipment(s) defines a single facility, while physical separation would define separate facilities. For example, the cab and electronic/electrical equipment located on the junction and subjunction levels of an Airport Traffic Control Tower (ATCT) are a single facility. An ATCT with a base building containing electronic equipment is an example of two facilities located at the same site. Other examples of two or more facilities include the ARSR-4 (the tower and base building are separate facilities) and Air Route Traffic Control Centers (ARTCC) with multiple buildings that must be treated as separate facilities. An example of a single facility (for purposes of this document) is a Remote Controlled Air to Ground Site (RCAG) collocated in a VHF Omni-directional Range (VOR) building. Contact the Office of Primary Responsibility (OPR) of this document for specific guidance on new facilities/systems.

4.1.1 Bonding Requirements

4.1.1.1 Resistance of Bonds

Unless otherwise specified in this standard, all bonds shall have a maximum DC resistance of 1 milliohm when measured between the bonded components with a 4-terminal milliohm meter.

4.1.1.2 Methods of Bonding

Bonding for electrical purposes shall be accomplished by a method that provides the required degree of mechanical strength, achieves the value of low and high frequency impedance required for proper functioning of the equipment. Soft soldered or brazed connections shall not be used for any part of the power grounding system, EES or the lightning protection system (air terminals, roof conductors, down conductors, fasteners, and conduit). Soft solder shall only be used to improve conductivity at joints already secured with mechanical fasteners. Soft solder shall not be used to provide mechanical restraint.

4.1.1.2.1 Exothermic Welds

Exothermic welds shall be allowed for any type of bond connection specified herein. Exothermic welds shall be used for all buried or subject to submersion connections. Where exothermic welds are not possible between certain materials, shapes, or in hazardous locations, i.e., near fuel tanks, where nearby objects are subject to damage, etc., connections using UL listed connectors shall be permitted. Exothermic welding shall be used for the permanent bonding of copper conductors to steel. Where the combustion products of a standard exothermic weld present problems, a smokeless exothermic process is commercially available and shall be used. All residual fluxes shall be removed or neutralized to prevent corrosion.

4.1.1.2.2 Welded Assemblies

Individual components of a welded assembly shall not require additional bonds between components if the DC resistance between individual components is less than 1 milliohm.

4.1.1.2.3 Dissimilar Metals

Mechanical bonds shall comply with Table I unless specifically approved by the OPR.

The legend shown below is for Table I and represents the four basic categories of possible metal interfaces.

no	Not suitable. This interface is highly likely to result in significant corrosion.
•	Suitable for indoor environments where temperature and humidity are controlled (non-condensing environment).
••	Suitable for all indoor environment.
•••	Suitable for all environments.

Table I. Mechanical Bonds Between Dissimilar Metals

METAL	Copper, solid or plate	Brass and bronze	Stainless Steel	Tin-plate; tin-lead solder	Aluminum, wrought alloys of the 2000 Series	Iron, wrought, gray or malleable, plain carbon and low alloy steels	Aluminum, wrought alloys other than 2000 Series aluminum, cast alloys of the silicon type	Aluminum, cast alloys other than silicon type, plated and chromate	Galvanized steel	Zinc, wrought zinc-base die-casting alloys; zinc plated
Copper, solid or plate	***	***	**	•	•	•	no	no	no	no
Brass and bronze	***	***	**	**	•	•	•	no	no	no
Stainless Steel	**	**	***	***	***	**	•	•	no	no
Tin-plate; tin-lead solder	•	**	***	***	***	**	**	•	no	no
Aluminum, wrought alloys of the 2000 Series	•	•	***	***	***	***	***	**	•	•
Iron, wrought, gray or malleable, plain carbon and low alloy steels	•	•	**	**	***	***	***	***	•	•
Aluminum, wrought alloys other than 2000 Series aluminum, cast alloys of the silicon type	no	•	•	**	***	***	***	***	•	•
Aluminum, cast alloys other than silicon type, plated and chromate	no	no	•	•	**	***	***	***	**	•
Galvanized steel	no	no	no	no	•	•	•	**	***	***
Zinc, wrought; zinc-based die-casting alloys; zinc plated	no	no	no	no	•	•	•	•	***	***

4.1.1.2.4 Mechanical Connections

4.1.1.2.4.1 Coupling of Dissimilar Metals

Compression bonding with bolts and clamps should be used between metals having acceptable couples depending on the location as shown in

Table I. When the base metals form couples that are not allowed, the metals shall be coated, plated, or otherwise protected with a conductive finish. MIL-STD-889 provides specific information in this area.

4.1.1.2.4.2 Bolted Connections for Electrical Bonding

Bolts shall be used primarily as mechanical fasteners for holding the component members of the bond in place. Bolts shall be tightened sufficiently to maintain the contact pressures required for effective bonding but shall not be over-tightened to the extent that deformation of bond members occurs. Disc springs (Belleville spring washers) shall be installed on all bolted connections $\frac{1}{4}$ inches diameter and greater to prevent loosening. Bolted joints other than those intentionally used to attach bonding straps or conductors, shall not be used in lieu of dedicated bonding jumpers.

- a) All bolted connections $\frac{1}{4}$ inches diameter and greater shall conform to the torque requirements in Table II.
- b) All bolted connections in corrosive, damp, or wet locations, $\frac{1}{4}$ inches diameter and greater shall utilize stainless steel bolts, nuts, and load distribution washers to meet the strength requirements of same size SAE Standard J429 Grade 5. All other locations shall use corrosion inhibited SAE Standard J429 Grade 5 nuts and bolts. Load distribution washers shall comply with ANSI B18.22.1 for stainless steel washers, Wide Series, Type B.
- c) Bolted connections $\frac{1}{4}$ inches diameter and greater shall be assembled in the order shown in Figure I. Additional load distribution washers, if used, shall be positioned directly underneath the bolt head. Disc springs shall be between the nut and the load distribution washer. Washers shall not be placed between bonded members. Load distribution washers be wide Series, Type B.

Table II. Torque Requirements for Bolted Bonds

Bolt Size	Torque (ft-lbs)	Bolt Load (lbs)	Washers Required	Solon Part Number*
1/4 in.	10	2500	3	4-EH-70-301
5/16 in.	21	4000	3	5-EH-80-301
3/8 in.	34	5500	3	6-EH-89-301
7/16 in.	55	7500	6	7-L-70-301
1/2 in.	83	10,000	2	8-18-125-301
9/16 in.	117	12,500	N/A	N/A
5/8 in.	167	16,000	3	10-EH-150-177
3/4 in.	288	23,000	3	12-EH-168-177
7/8 in.	452	31,000	3	14-EH-168-177
1 in.	567	40,000	3	15-H-187-177

*Other manufacturers of disc spring washers are equally suitable

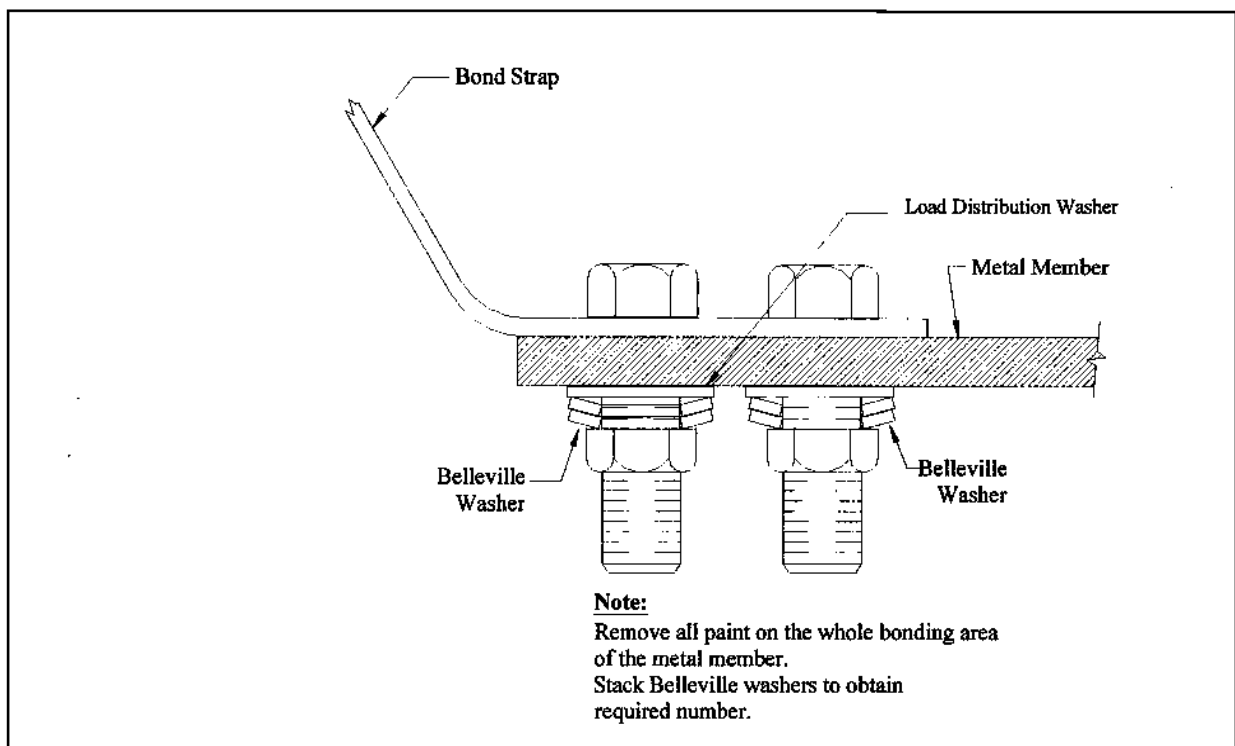


Figure I. Order of Assembly for Bolted Connections

4.1.1.2.4.3 Sheet Metal Screws

Sheet metal screws shall not be used to provide an electrical bond.

4.1.1.2.4.4 Hydraulically Crimped Terminations

Where crimped connectors are used for conductors 6 AWG or larger, the connectors shall be accomplished hydraulically using a minimum force of 12 tons concentrically applied.

4.1.1.2.4.5 Soldering

The use of silver solder to improve mechanical bonds by excluding contaminants from the mating surfaces shall be allowed. Mechanical bonds shall be mechanically secured prior to applying solder to prevent cold solder joints. Soldered mechanical connections shall not be used for any part of the power grounding system or the lightning protection system. See FAA Order 6950.20, Chapter 5, paragraph 99 for additional information.

4.1.1.2.4.6 Riveting

Rivets shall be employed solely as mechanical fasteners to hold multiple smooth, clean metal surfaces together or to provide a mechanical load bearing capability to a soldered bond.

4.1.1.3 Bonding Straps and Jumpers

Bonding straps, including jumpers, shall conform to the following:

- (a) Bonding jumpers shall be insulated except those used under a raised floor which shall be bare. Bonding jumpers for structural steel, rebar, connected to the EES, the lightning protection system, and any plenum or environmental airspace shall be bare also. Short bonding straps may be bare. (This requirement is to maintain compliance with the requirements of the NEC)
- (b) Bonding straps shall be attached to the basic component rather than through any adjacent parts.
- (c) Bonding straps shall be installed so that the electrical bond is not affected by motion or vibration.
- (d) Braided bonding straps shall not be used for bonding transmitters or other sources of radio frequency (RF) fields.
- (e) Bonding straps shall be installed whenever possible in areas accessible for maintenance and inspection.
- (f) Bonding straps shall be installed so they will not restrict movement of the components being bonded or other components nearby which must be able to move as part of normal functional operation.
- (g) Two or more bonding straps shall not be connected in series to provide a single bonding path.
- (h) The method of installation and point of attachment of bonding straps shall not weaken the components to which they are attached.
- (i) Bonding straps shall not be compression-fastened through non-metallic material.
- (j) Bonding straps shall be designed not to have resonant impedances at equipment operating frequencies. Two short, low-impedance grounding straps between the signal reference structure and two corners of the equipment should be used. These straps shall be connected as far apart as possible on the equipment (ideally on opposite corners) in order to reduce mutual inductance and they shall have few bends or sags. Two straps with a 20% to 30% difference in length should be used so that if one strap experiences resonance, limiting current flow, the other strap will not.
- (k) The length of the equipment bonding conductor connections shall be as short as possible and ideally be limited to 1/20th of a wavelength of the signal frequency, e.g., about six inches at 100 MHz.
- (l) Broad flat conductors, with a large surface area (at least one inch wide) shall be used for bonding straps since they have a lower inductance than round conductors. All bonding straps shall be fabricated with integral terminations that approximate the width of the strap, permitting proper terminations. Lower impedance can be achieved by multiple bonds.

4.1.1.4 Fasteners

Fastener materials for bonding aluminum and copper jumpers to structures shall conform to the materials listed in Table I.

4.1.1.5 Temporary Bonds

Alligator clips and other spring loaded clamps shall be employed only as temporary bonds while performing repair work on equipment or facility wiring.

4.1.1.6 Inaccessible Locations

All bonds in permanently concealed or inaccessible locations shall be exothermically welded.

4.1.1.7 Surface Preparation

All surfaces to be bonded shall be thoroughly cleaned to remove all dirt, grease, oxides, nonconductive films, or other foreign material. Paints and other coatings shall be removed to expose the base metal.

4.1.1.7.1 Area to Be Cleaned

Clean all surfaces at least $\frac{1}{4}$ inches (6.4 mm) beyond all sides of the larger bonded area on all mating surfaces.

4.1.1.7.2 Final Cleaning

Clean surfaces with a solvent suitable for electrical work immediately prior to assembly.

4.1.1.7.2.1 Clad Metals

Clean clad metal to a bright, shiny, smooth surface without penetrating the cladding. Wipe the cleaned area with solvent and allow to air dry before completing the bond.

4.1.1.7.2.2 Aluminum Alloys

A conductive finish shall be applied to aluminum mating surfaces after cleaning to a bright finish.

4.1.1.7.3 Completion of the Bond

Mating surfaces shall be joined within 2 hours after cleaning if an intentional protective coating has been removed from the metal surface. If delays beyond two hours are necessary in corrosive environments, the cleaned surfaces must be protected with an appropriate coating that must be removed before completion of the bond.

4.1.1.7.4 Refinishing of Bond

Where practicable restore areas around bonds so as to match the original finish.

4.1.1.7.5 Surface Plating or Treatments

Surface treatments that include plating provided for added abrasion resistance or corrosion protection shall offer high conductivity. Unless suitably protected from the atmosphere, silver and other easily tarnished metals shall not be used to plate bond surfaces, except where an increase in surface contact resistance cannot be tolerated.

4.1.1.8 Bond Protection

All bonds shall be protected against weather, corrosive atmospheres, vibration, and mechanical damage. Under dry conditions, apply a compatible corrosion preventive or sealant, within 24 hours of assembly of the bond materials. Under conditions exceeding 60% humidity, seal the bond with a compatible corrosion preventive or sealant within 1 hour of joining.

4.1.1.8.1 Paint

If a paint finish is required on the final assembly, the bond shall be sealed with the recommended finish. Care shall be taken to assure that all means by which moisture or other contaminants

enter the bond are sealed. A waterproof type of paint or primer shall be used if the recommended finish is not waterproof.

4.1.1.8.2 Compression Bonds in Protected Areas

Sealing is not required for compression bonds between copper conductors or between compatible aluminum alloys located in readily accessible areas that are not exposed to moisture, corrosive fumes, or excessive dust.

4.1.1.8.3 Corrosion Protection

All exterior and interior bonds exposed to moisture or high humidity shall be protected against corrosion. All interior bonds made between dissimilar metals shall be protected against corrosion in accordance with paragraph 4.1.1.2.3 and paragraph 4.1.1.2.4.1. All exothermic welds shall be cleaned of all residual slag. Protection shall be provided by a moisture proof paint conforming to the requirements of FAA-STD-012 or shall be sealed with a silicone or petroleum-based sealant to prevent moisture from reaching the bond area. Bonds protected by conductive finishes (alodine, iridite, et. al.) shall not require painting to meet the requirements of this standard.

4.1.1.9 Bonding across Shock Mounts

Bonding straps installed across shock mounts or other suspension or support devices shall not impede the performance of the mounting device. They shall be capable of withstanding the anticipated motion and vibration requirements without suffering metal fatigue or other failures.

4.1.1.10 Enclosure Bonding

Directly bond subassemblies and equipment at the areas of physical contact with the mounting surface.

4.1.1.11 Subassemblies

Utilize the maximum possible contact area when bonding subassemblies to the chassis. All feed throughs, filters, and connectors shall be bonded around the periphery to the subassembly enclosure to maintain shield effectiveness. Covers shall exhibit intimate contact around their periphery, and contact shall be achieved and maintained through the use of closely spaced screws or bolts, or the use of resilient conductive gaskets, or both. Note: COTS equipment should be treated as a sealed unit for the purposes of this requirement.

4.1.1.12 Equipment

The chassis or case of equipment shall be directly bonded to the rack, frame, or cabinet in which it is mounted. Clean all flange surfaces and the contact surface on the supporting element of all paint or other insulating substances in accordance with the requirements of paragraph 4.1.1.7. Fasteners shall maintain sufficient pressure to assure adequate surface contact to meet the bond resistance requirements in paragraph 4.1.1.1. Captive nuts and sheet metal screws shall not be used for fasteners. If equipment must remain operational when partially or completely withdrawn from its mounted position, the bond shall be maintained by a moving area of contact or by the use of a flexible bonding strap. Mechanical designs shall employ direct bonding, without straps, whenever feasible.

4.1.1.13 Connector Mounting

All metal or metallized connectors shall be mounted so that electrical contact is maintained between the connector body and the panel to which it is mounted. Bonding shall be accomplished completely around the periphery of the flange of the connector. Both the flange surface and the mating area on the panel shall be cleaned in accordance with paragraph 4.1.1.7. All nonconductive material shall be removed from the panel as illustrated in Figure II. After mounting of the connector, the exposed area of the panel shall be repainted or otherwise protected from corrosion in accordance with paragraph 4.1.1.8.

4.1.1.14 Shield Terminations

Cable shields shall be terminated in the manner specified by paragraphs 4.1.2.3.2 and 4.1.2.3.3. Shields of axial cables shall be fastened tightly to the cable connector shell with a compression fitting or soldered connection. The cable shall be able to withstand the anticipated use without becoming noisy or suffering a degradation in shielding efficiency. Axial connectors shall be of a material that is corrosion resistant in keeping with requirements of FAA-G-2100. Low frequency shields shall be soldered in place or, if solderless terminals are used, the compressed fitting shall afford maximum contact between the shield and the terminal sleeve. Shield pigtails shall extend less than 1 inch from the point of breakaway from the center conductors of the cable.

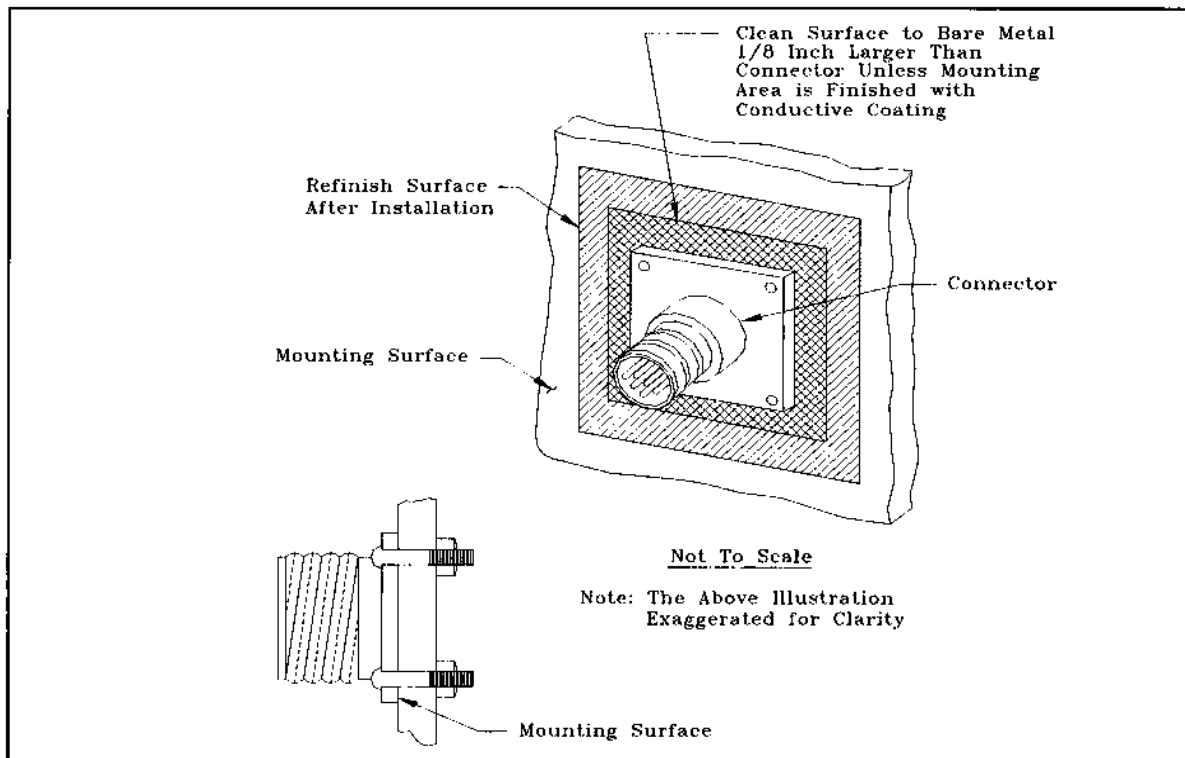


Figure II. Bonding of Connectors to Mounting Surface

4.1.1.15 RF Gaskets

Conductive gaskets shall be made of corrosion resistant material, shall offer sufficient conductivity to meet the resistance requirements of paragraph 4.1.1.1, and shall possess adequate

strength, resiliency, and hardness to maintain the shielding effectiveness of the bond. The surfaces of contact with the gasket shall be smooth and free of insulating films, corrosion, moisture, and paint. The gasket shall be firmly affixed to one of the bond surfaces by screws, conductive cement, or other means that do not interfere with the effectiveness of the gasket; or a milled slot shall be provided that prevents lateral movement or dislodging of the gasket when the bond is disassembled. Gaskets shall be a minimum of $\frac{1}{8}$ inch wide. The gasket as well as the contact surfaces shall be protected from corrosion.

4.1.2 Shielding Requirements

4.1.2.1 Design

The facility design and construction shall incorporate both protective shields to attenuate radiated signals, and separation of equipment and conductors to minimize the coupling of interference. The equipment design shall incorporate component compartments and overall shields as necessary to meet the electromagnetic susceptibility and emission requirements of MIL-STD-461 as required by NAS-SS-1000 and FAA-G-2100. In addition, the design shall provide the shields necessary to protect personnel.

4.1.2.2 Facility Shielding

Shielding of facility buildings, shelters or equipment spaces shall be provided when other facility or environmental sources of radiation are of sufficient magnitude to degrade the operation and performance of electronic equipment or system. Where rebar or a rudimentary Faraday cage exists, it shall be connected to the EES with a minimum 2 AWG copper conductor that is applied via an exothermic weld or a hydraulically crimped termination.

4.1.2.3 Conductor and Cable Shielding

Conductor and cable shielding shall comply with the following sub-paragraphs:

4.1.2.3.1 Signal Lines and Cables

Cables consisting of multiple twisted pairs shall have individual shields for each twisted pair.. The shields shall be isolated from each other. Cables with an overall shield shall have the shield insulated and isolated from the individual shields..

4.1.2.3.2 Termination of Individual Shields

Shields of pairs of conductors, line shields, and the shield of cables containing unshielded conductors shall be terminated in accordance with the following:

- (a) Shields shall be terminated to ensure correct equipment operation.
- (b) Shield terminations shall employ minimum length pigtails between the shield and the connection to the bonding halo or ferrule ring and between the halo or ferrule ring and the shield pin on the connector. The unshielded length of a signal line shall not exceed 1 inch (25 mm) with not more than $\frac{1}{2}$ inch (13 mm) of exposed length as the desired goal.
- (c) Shields, individually and collectively, shall be isolated from overall shields of cable bundles and from electronic equipment cases, racks, cabinets, junction boxes, conduit, cable trays, and elements of the electronic multipoint ground system. Except for one interconnection, individual shields shall be isolated from each other. This isolation shall be maintained in

junction boxes, patch panels and distribution boxes throughout the cable run. When a signal line is interrupted such as in a junction box, the shield shall be carried through. The length of unshielded conductors shall not exceed 1 inch (25 mm). To meet this requirement, the length of shield pigtail longer than 1 inch shall be allowed but shall be the minimum required.

- (d) Circuits and chassis shall be designed to minimize the distance from the connector or terminal strip to the point of attachment of the shield grounding conductor to the electronic signal reference. The size of the wire used to extend the shield to the circuit reference shall be as large as practical but shall not be less than 16 AWG or the maximum wire size that will fit the connector pin. A common shield ground wire for input and output signals, for both high level and low level signals, for signal lines and power conductors, or for electronic signal lines and control lines shall not be used.
- (e) Nothing in this requirement shall preclude the extension of the shields through the connector or past the terminal strip to individual circuits or chassis if required to minimize unwanted coupling inside the electronic equipment. Where extensions of this type are necessary, overall cable or bundle shields grounded in accordance with paragraph 4.1.2.3.3 shall be provided.

4.1.2.3.3 Termination of Overall Shields

Cables that have an overall shield over individually shielded pairs shall have the overall shield grounded at each end unless otherwise required by the equipment. Grounding through an SPD is permissible if grounding both ends of the conductors degrades system performance. The drain wire if present shall be grounded the same as the shield.

- (a) Cable shields terminated to connectors shall be bonded to the connector shell as shown in Figure IIIa or Figure IIIb. The shield shall be carefully cleaned to remove dirt, moisture, and corrosion products. The connector securing clamp shall be carefully tightened to assure that a low resistance bond to the connector shell is achieved completely around the circumference of the cable shield. The bond shall be protected against corrosion in accordance with paragraph 4.1.1.8. The panel-mounted part of the connector shall be bonded to the mounting surface in accordance with paragraph 4.1.1.13.
- (b) Where the cable continuity is interrupted, such as in a junction box, the shield shall be carried through and grounded at the box. The length of unshielded conductors shall not exceed 1 inch (25 mm). If necessary, the shield pigtail shall be allowed longer than 1 inch to reach ground but shall be as short as possible.
- (c) Cables which penetrate walls or panels of cases or enclosures without the use of connectors shall have their shields bonded to the penetrated surface in the manner shown in Figure IIIc. Overall shields shall be terminated to the outer surface of cases to the maximum extent possible.
- (d) Grounding of overall shields to terminal strips shall be as shown in Figure IV.

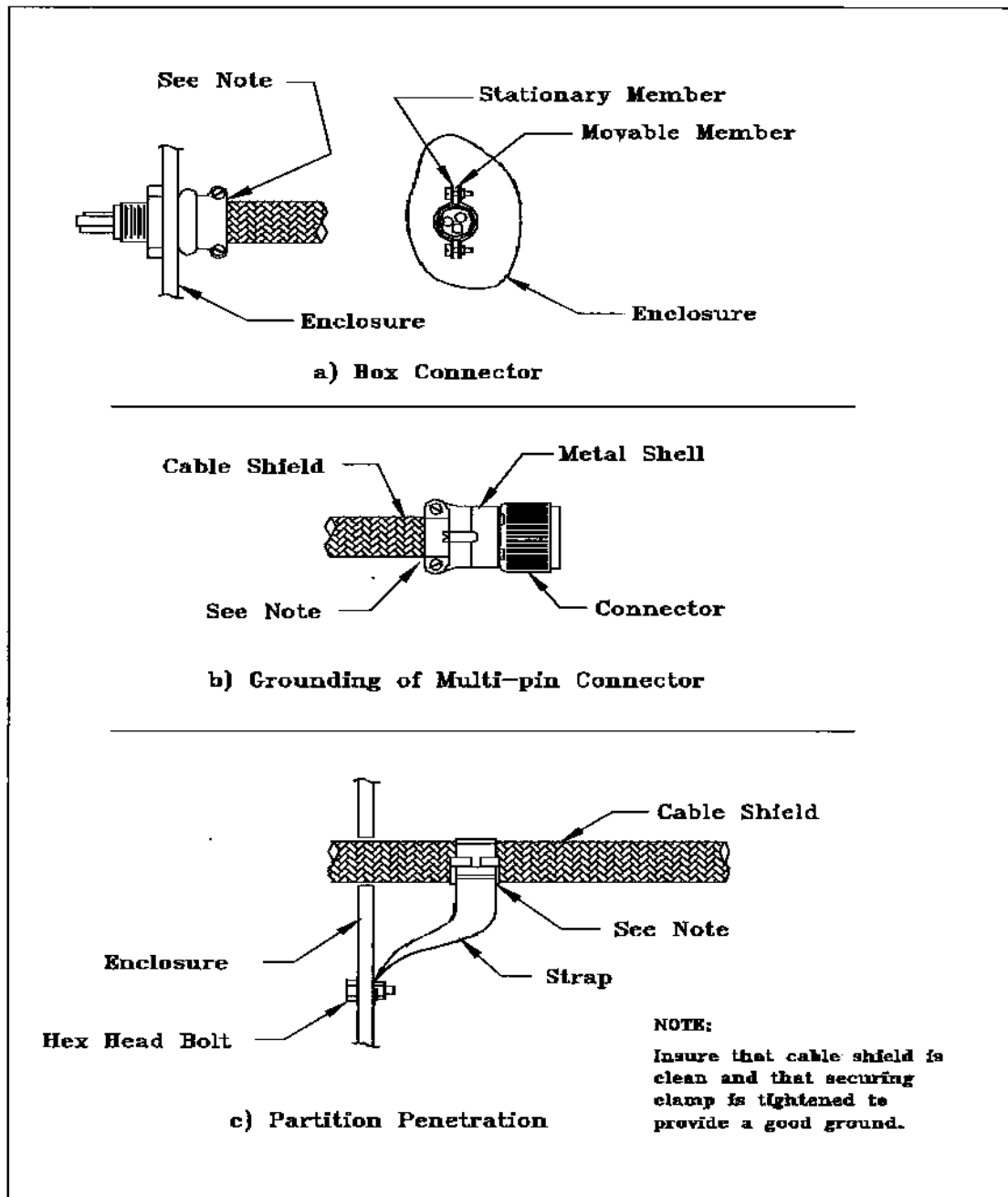


Figure III. Grounding of Overall Cable Shields to Connectors and Penetrating Walls

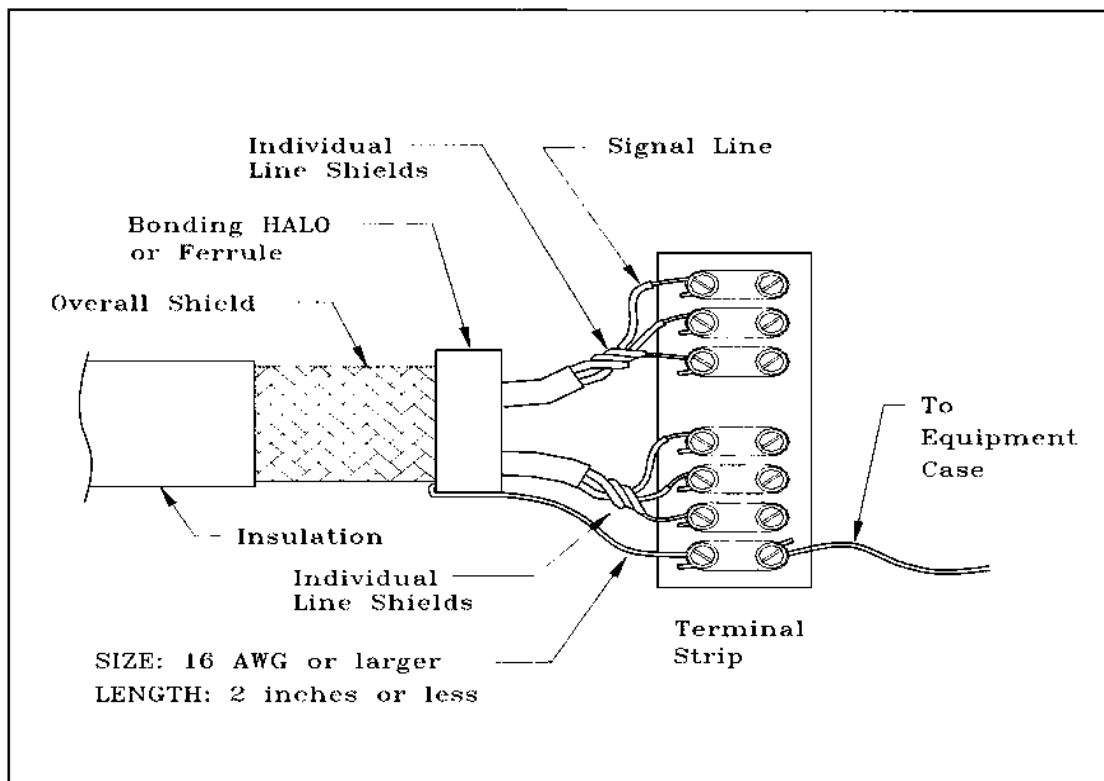


Figure IV. Grounding of Overall Cable Shield to Terminal Strip

4.1.2.4 Electromagnetic Environment Control

Shielding shall be integrated with other basic interference control measures such as filtering, wire routing, cable and circuit layout, signal processing, spectrum control, and frequency assignment to achieve the highest operational reliability of the equipment. Implementation procedures necessary to achieve the required filtering and shielding shall be detailed in the control plan described in paragraph 4.1.4.2 to include material requirements, shield configurations, placement and installation limitations, gasket utilization, filter integration, aperture control, bonding and grounding requirements, and wire routing and circuit layout constraints.

4.1.2.4.1 Space Separation

The design and layout of facilities shall physically separate electronic equipment and conductors that produce interference from equipment and conductors that are susceptible to interference. The minimum separation distance between power and signal cables shall be in accordance with Table III.

4.1.2.4.2 Wire and Cable Routing

The routing and layout of wires, conductors and cables shall be performed in a manner that does not jeopardize the integrity of the equipment shield. Signals with power level differences of greater than 20dB shall be routed as far apart as feasible. AC power conductors and control lines shall be routed away from sensitive digital or other susceptible circuits. Shielded cables shall be

used where needed to prevent emissions and/or to provide shielding. Cable shields shall be grounded in accordance with the requirements of paragraphs 4.1.2.3.2 and 4.1.2.3.3

Table III. Minimum Separation Distance Between Signal and Power Conductors.

Condition	Circuit Power Level		
	< 2 kVA	2-5 kVA	> 5 kVA
Unshielded power lines or electrical equipment in proximity to signal conductors in open cable tray or nonmetal raceway.	5 in. (127 mm)	12 in. (305 mm)	24 in. (610 mm)
Unshielded power lines or electrical equipment in proximity to signal conductors in a grounded metal raceway.	2.5 in. (64 mm)	6 in. (152 mm)	12 in. (305 mm)
Power lines enclosed in a metal raceway (or equivalent shielding) in proximity to signal conductors in a metal raceway.	-	3 in. (76 mm)	6 in. (152 mm)

4.1.2.4.3 Gaskets

Conductive gaskets conforming to paragraph 4.1.1.15 shall be utilized at joints, seams, access covers, removable partitions, and other shield discontinuities to the extent necessary to provide interference-free operation of the equipment under normal use and environmental conditions. Finger stock used on doors, covers, or other closures subject to frequent openings shall be installed in a manner that permits easy cleaning and repair.

4.1.2.4.4 Filter Integration

Filters on power, control, and signal lines shall be installed in a manner that maintains the integrity of the shield. AC power filters shall be completely shielded with the filter case grounded in accordance with paragraph 4.3.4.4. Filters for control and signal lines shall be placed as close as possible to the point of penetration of the case to avoid long, unprotected paths inside the equipment.

4.1.2.4.5 Bonding and Grounding of Compartment Shields

All shields shall be grounded. Bonding shall be accomplished in accordance with paragraph 4.1.1.

4.1.3 Electrostatic Discharge (ESD) Requirements

Modern electronic and electronically controlled electrical equipment is susceptible to damage from Electrostatic Discharge (ESD). The requirements of this section are designed to reduce the frequency and minimize the effects of ESD events. All electronic circuitry that contains miniaturized or solid-state components shall be considered ESD susceptible.

4.1.3.1 ESD Sensitivity Classification

Classification of items as ESD sensitive shall be in accordance with the Human Body Model testing procedures and requirements of ANSI/ESD STM5.1. Electronic parts, components, and assemblies shall be classified as either sensitive or supersensitive. Items that will fail from ESD at 1000 to 16000 Volts shall be classified as ESD sensitive. Those items that will fail below 1000 Volts shall be classified as supersensitive. Any exceptions to this guidance shall be through the OPR of this document. Devices with a sensitivity of less than +/- 200 Volts require additional ESD protection measures than those specified in this standard. ESD susceptible items shall not be exposed to an electrostatic field (E-field) greater than 100 Volts/meter or brought closer than 24" to known static generators or non-essential insulative materials.

4.1.3.2 ESD Protection Requirements

All NAS electrical and electronic equipment, subassemblies, and components subject to damage from exposure to electrostatic fields or electrostatic discharge (ESD) shall be protected in accordance with the protection requirements herein. ESD controlled areas shall be provided for all operations, storage, repair, and maintenance spaces used for electrical and electronic equipment or subassemblies that are subject to damage from static electricity or ESD.

4.1.3.3 Classification of Materials

4.1.3.3.1 General

Most materials and products that are used to control and prevent ESD are classified by their resistive properties as conductive or static dissipative. Antistatic materials are an exception to this and are classified by their propensity to not generate static electricity from triboelectric charging. Any material used for construction of ESD protected areas (with the exception of antistatic materials) shall meet the resistive properties specified for type and use of the material. Materials that will tribocharge to greater than +/- 200 Volts (EIA-625), if the material were to contact and separate from itself or from other materials, shall not be used in ESD controlled areas.

4.1.3.3.2 Static Conductive Materials

Those materials with a surface resistivity less than 1.0×10^5 ohms/square when tested per ANSI/ESD S11.11 shall be considered conductive. Conductive ESD control materials shall not be used for ESD control work surfaces, tabletop mats, floor mats, flooring, or carpeting where the threat of personnel contact with energized electrical or electronic equipment exists. Conductive ESD control materials are not to be used in any other application where their use could result in electromagnetic interference (EMI) or radio frequency interference (RFI) that would be created by rapid, high voltage ESD spark discharges. Any exceptions to this guidance shall be through the OPR of this document.

4.1.3.3.3 Electrostatic Shielding Materials

Electrostatic shielding materials are a subset of conductive materials with a surface resistance equal to or less than 1.0×10^3 ohms when tested per ANSI/ESD S11.11. Electrostatic shielding materials shall be allowed as barriers for protection of ESD sensitive items from electrostatic fields where required.

4.1.3.3.4 Electromagnetic Shielding Materials

Electromagnetic shielding materials with highly conductive surfaces (< 10 ohms) or specifically designed composite materials that absorb and reflect electromagnetic radiation over a broad range of frequencies shall also be allowed as barriers where required to protect ESD sensitive items from electromagnetic fields.

4.1.3.3.5 Static Dissipative Materials

Those materials with a surface resistivity greater than 1.0×10^5 ohms/square but less than or equal to 1.0×10^{12} ohms/square when tested per ANSI/ESD S11.11 are classified as static dissipative materials. Static dissipative materials with a surface resistance less than or equal to 1.0×10^9 ohms shall be used to provide controlled bleed-off of accumulated static charges in ESD controlled areas. Static dissipative materials with a surface resistance of greater than 1.0×10^9 ohms shall not be used for applications where controlled bleed-off of accumulated static charges is essential. Any exception to this guidance shall be through the OPR of this document.

4.1.3.3.6 Antistatic Materials

Any material that inhibits or has a low propensity to generate static electricity from triboelectric charging shall be considered antistatic. Antistatic ESD control items and materials used for construction of ESD controlled areas in new or renovated facilities shall not tribocharge to greater than ± 200 Volts when being used for their intended application. Antistatic materials with a surface resistance greater than 1×10^9 ohms shall not be used for ESD protective work surfaces, tabletop mats, floor mats, flooring, and carpeting when charge dissipation is the primary consideration. If the surface resistance (R_{H}) of an antistatic material is greater than 10^{12} ohms it shall normally be considered to be too resistive for use in ESD controlled areas. Use of antistatic items and materials that utilize hygroscopic surfactants that depend on ambient humidity to promote absorption of water shall be limited. Only antistatic materials that are intrinsically antistatic and will retain their antistatic properties shall be used in ESD controlled areas. Exceptions to this guidance shall be through the OPR of this document.

4.1.3.3.7 Static-Generative Materials, Non-Conductors, and Insulators

Materials having a surface resistance greater than 1.0×10^{12} ohms (ANSI/ESD S11.11) shall be considered to be insulators and a possible source of triboelectric charging. These include common plastics, Plexiglas, Styrofoam, Teflon, nylon, rubber, untreated polyethylene, and polyurethane. Their use shall be minimized where ESD sensitive items are located.

4.1.3.4 Protection of ESD Susceptible and Sensitive Items

4.1.3.4.1 Static Protected Zone

A static protected zone shall be a volume or area where unprotected ESD sensitive items will be safe from direct contact with electrostatic potentials greater than ± 200 volts, electrostatic fields greater than 100 volts/meter, or radiated electromagnetic interference and radio frequency interference produced by rapid, high voltage ESD spark discharges. Static protected zones shall be incorporated into the construction of ESD special protection areas, ESD protected workstations, and ESD protected storage areas.

4.1.3.4.2 ESD Special Protection Areas

Special protection areas shall be designated areas that require extraordinary ESD control measures to accomplish the following:

- (a) Minimize triboelectric charging.
- (b) Control bleed-off and dissipation of accumulated static charges.
- (c) Neutralize charges.
- (d) Minimize the effects of E-Fields, H-Fields, and EMI and RFI from ESD spark discharges.

Areas within a facility that shall be designated as ESD special protection areas are:

- (a) Air traffic operations areas (e.g., tower cab, TRACON, ARTCC control rooms, AFSS, etc.).
- (b) Electronic equipment rooms.
- (c) Storage areas for ESD susceptible components, subassemblies, circuit cards, etc.
- (d) Areas that contain personal computers and Local Area Networks (LANs) that are connected to or interface directly with NAS electronic equipment.
- (e) All other locations where jacks, plug in connectors or interfaces of ESD sensitive electronic equipment are exposed and vulnerable to damage from ESD by direct human contact shall also be designated as ESD special protection areas.

4.1.3.4.3 ESD Controls Required for ESD Special Protection Areas

The following minimum ESD control measures shall be implemented in all areas designated as ESD special protection areas:

4.1.3.4.3.1 ESD Groundable Point (GP)

Each ESD control material, surface, or item used in an ESD controlled area shall have a designated groundable point (GP) to provide ease of connection to the nearest Signal Reference Structure (SRS).

4.1.3.4.3.2 Grounded Static Dissipative Surfaces

All work surfaces which include work surface laminates, paints and sealers, writing surfaces, table tops, consoles, workbenches, and table top mats shall be static dissipative and connected to any SRS in the area served – except to a single point ground system. The point-to-point resistance and surface to ground resistance of static dissipative work surfaces shall be greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms (ANSI/ESD S4.1).

4.1.3.4.3.3 Limiting the Use of Non-ESD Control Materials

Materials that will tribocharge (e.g., generate electrostatic potentials by contact and separation with themselves or other materials) shall not be used for construction in ESD special protection areas. Insulative materials and any other non-essential triboelectric charge generators that generate potentials in excess of +/- 200 Volts shall not be permitted within 24 inches of ESD special protection areas.

4.1.3.4.3.4 Static Dissipative Chairs

Chairs (e.g., seating) provided for ESD special protection areas shall incorporate a continuous path between all chair elements (e.g., cushion and arm rests) to the ground points of greater than

1.0×10^5 ohms to less than 1.0×10^9 ohms. The ground points for ESD chairs are static dissipative or conductive casters that provide electrical continuity from all elements of the chair to ESD control carpeting, tile, or floor mats that are properly bonded to any SRS – except to a single point ground system. ESD control chairs must be tested and meet the requirements of ANSI/ESD STM12.1.

4.1.3.4.3.5 Static Dissipative ESD Control Floor Coverings

Static dissipative ESD control floor coverings shall include static dissipative tile, carpeting, static limiting floor finishes, and floor mats. Floor coverings in ESD special protection areas shall have a point-to-point resistance and surface-to-ground resistance of greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms (ANSI/ESD S7.1). These floor coverings shall be bonded to any SRS in the area served in accordance with paragraphs 4.1.3.4.3.1 and 4.1.3.4.8 – except to a single point ground system. In circumstances involving extremely static sensitive equipment a static conductive floor covering with a lower resistance limit of 2.5×10^4 ohms (UL779) shall be implemented when it is part of a designed approach for ESD control for the equipment approved by the OPR of this document. This designed approach shall include all steps required to produce an electrically safe working environment.

4.1.3.4.3.6 Relative Humidity Control

Relative humidity in ESD special protection areas shall be maintained within the range of 40 to 60%.

4.1.3.4.4 ESD Signs, Labels, Cautions, and Warnings

ESD warning signs that include ESD sensitive device warning symbols with appropriate cautions and warnings shall be posted in ESD special protection areas and all other ESD controlled areas. Exterior cabinets of ESD sensitive electronic equipment shall also be marked or labeled with an ESD sensitive device symbol with a warning that is visible from at least 3 feet. Any signs or labels shall be consistent with the requirements of ANSI/ESD S8.1.

4.1.3.4.5 ESD Protected Workstations

These workstations are for the maintenance and repair of ESD sensitive equipment.

4.1.3.4.5.1 ESD Protected Workstation Minimum Requirements

All ESD control items at an ESD protected workstation shall be connected to a common groundable point, i.e., ESD ground, that is connected to any SRS in the area served – except to a single point ground system. ESD protected workstations shall be free of all non-essential static charge generators; and provide a means of personnel grounding. They shall have a grounded static dissipative work surface, and grounded static dissipative ESD control floor or mat. Storage containers provided at ESD protected workstations shall provide ESD protection and shall also be connected to the ESD ground. All outlets at ESD protected workstations shall be protected with ground fault circuit interruption (GFCI) capability to minimize danger to grounded personnel from electrical shock.

4.1.3.4.5.2 Use of Ionization

Selective use of bench top or area ionizers shall be allowed at ESD protected workstations if static generative items (e.g., insulators) are deemed essential and cannot be removed from ESD

protected workstation areas or if grounding of mobile personnel would be cumbersome or create a safety hazard.

4.1.3.4.5.3 Identification of ESD Protected Workstations

The boundaries of all ESD protected workstations shall be clearly defined. The boundaries of ESD protected workstations shall extend a minimum of 24 inches beyond where ESD sensitive items will be located and will be marked with yellow tape. ESD warning signs that are yellow with black markings and lettering shall be posted that will be visible to anyone entering these areas. Signs shall include an ESD sensitive electronic device warning symbol and appropriate warnings and cautions.

4.1.3.4.6 ESD Protective Storage Areas

4.1.3.4.6.1 Shelves, Bins, and Drawers

Shelves, bins, and drawers shall be static dissipative and electrically continuous with the support structure of the storage shelves, bins, or container.

4.1.3.4.6.2 Grounding

The storage container metal support structure shall have a groundable point (GP) that shall be connected to the nearest SRS – except to a single point ground system. The resistance from the ground point of storage containers, shelving, cabinets, and bins used to store ESD sensitive items to the nearest SRS shall be less than one ohm.

4.1.3.4.6.3 Personnel Grounding

Wrist straps shall be equipped with one megohm or greater series resistance to protect personnel. Standard 0.157 inch banana jacks for personnel grounding wrist straps shall be connected to the ESD ground or directly to any SRS in the area served – except to a single point ground system. The resistance from a banana jack to a ground point and/or to the nearest SRS – except to a single point ground system shall be less than one ohm.

4.1.3.4.6.4 Materials Prohibited in ESD Protective Storage Areas

Static generative (e.g., insulative) materials shall not be used for construction in any areas where ESD sensitive items will be stored. All materials that can generate potentials greater than +/- 200 Volts shall be a minimum of 24 inches from ESD protected storage areas.

4.1.3.4.6.5 Resistance to ESD Ground for Shelves, Drawers, and Bins

All surfaces and drawers of the storage media provided shall be made with static dissipative materials and meet the requirements and be tested the same as work surfaces (ANSI/ESD S4.1). The surface-to-surface resistance (R_{tt}) and surface-to-ground resistance (R_{tg}) from the shelves, bins, and drawers of storage containers that will be used to store unprotected ESD sensitive items shall be greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms (ESD ADV53.1).

4.1.3.4.6.6 Identification of ESD Protective Storage Areas

The boundaries of all ESD protective storage areas shall be clearly defined. Boundaries of ESD protective storage areas shall extend a minimum of 24 inches beyond where ESD sensitive items will be located and will be marked with yellow tape. ESD warning signs that are yellow with

black markings and lettering shall be posted that will be visible to anyone entering these areas. Signs shall include an ESD sensitive electronic device warning symbol and appropriate warnings and cautions.

4.1.3.4.7 Hard and Soft Grounds

4.1.3.4.7.1 Hard Grounds

Any item, material, or product that is a part of the ESD control system that is intentionally or unintentionally connected to an ESD ground, or directly to any SRS in the area served – except to a single point ground system – shall be considered to be hard grounded. Unless specified otherwise or justified by the OPR for this document, ESD control worksurfaces, cabinets, flooring, carpeting, test equipment, and any other items used for ESD control shall be hard grounded.

4.1.3.4.7.2 Soft Grounds

A soft ground is an intentional connection to ground through a series current limiting resistor. Soft grounding shall only be used in personnel grounding skin contact devices such as wrist straps, leg or ankle straps, conductive shoes, and heel or toe grounders. The nominal resistance of the resistor used for soft grounding of personnel shall be greater than 1.0×10^6 ohms unless otherwise specified by the OPR for this document. All other elements of the ESD control system shall be hard grounded.

4.1.3.4.8 ESD Control Flooring and Floor Coverings

All ESD control floors and floor coverings shall have a point to point resistance and a surface to ground resistance of greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms (ESD STM7.1). ESD control flooring and floor coverings include vinyl tile, vinyl sheet, carpet, carpet tile, carpet tile with positioning buttons and others but not to include applied coatings.

These control floors and floor coverings shall be installed, grounded, and initially tested only by trained installers. A representative ten-foot-square section of the floor system shall be tested and the results approved and accepted by FAA personnel, prior to installation of the full floor system.

ESD control floors and floor coverings shall be bonded to the nearest SRS at a minimum of four locations. The connections and method shall be recommended by the floor manufacturer and approved by the OPR. These connections shall utilize copper: strip, foil, conductive fabric ribbon, or stranded wire. Electrical contact shall be made with the underside of the floor material or connections may be embedded in the conductive permanent or releasable adhesive used to lay the floor. The ESD control flooring shall not be bonded to any single point ground system.

4.1.3.4.8.1 Surface Resistance (R_{tt})

Surface resistance (R_{tt} - Resistance top-to-top or surface-to-surface) of ESD control floors, carpets or floor mats shall be greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms (ANSI/ESD S7.1). A minimum of five readings shall be taken at different locations on the floor surface and averaged together for each 500 square feet (or fraction thereof) of floor surface. These readings shall be recorded in the FRDF.

4.1.3.4.8.2 Resistance Surface-to-Ground (R_{tg})

Resistance from the floor surface to ground (R_{tg} - Resistance top-to-ground) of ESD control floors, carpets or floor mats shall be greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms (ANSI/ESD S7.1). A minimum of five readings shall be taken at different locations on the floor surface and averaged together for each 500 square feet (or fraction thereof) of floor surface. These readings shall be recorded in the FRDF.

4.1.3.4.8.3 Triboelectric Charging Limitation

ESD control floors, carpets, or floor mats shall limit and control generation and accumulation of static charges to less than +/- 200 Volts in ESD controlled area.

4.1.3.4.9 ESD Requirements for Raised Floors

4.1.3.4.9.1 Resistance from Carpet Surface to Pedestal Understructure

Carpet tiles shall have a resistance from the carpeted surface of the raised floor to the pedestal greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms.

4.1.3.4.9.2 Panel to Floor Understructure Resistance

Panel-to-understructure (metal-to-metal) contact resistances between individual raised floor panels and the floor understructure shall be 10 ohms or less.

4.1.3.4.9.3 Carpet Tile Installation on Raised Floor Panels

Install individual carpet tiles on raised floor panels with either permanent or releasable conductive adhesive depending on the application.

4.1.3.4.9.4 Grounding

There shall be a minimum of four connections per 1,000 square feet of installed ESD control carpeting from the carpeting undersurface and conductive adhesive to the raised floor panel understructure. The Connections and method shall be in accordance with paragraph 4.1.3.4.8.

4.1.3.4.10 ESD Protective Worksurfaces

Static dissipative materials or electrostatic dissipative laminates shall be used to cover all worksurfaces, consoles, workbenches, and writing surfaces in areas that contain ESD sensitive equipment and in all areas designated as ESD special protection areas, static-safe zones, and ESD protected areas.

4.1.3.4.10.1 Requirements for ESD Protective Worksurfaces

Static dissipative worksurfaces shall be provided for new or upgrade facilities unless otherwise specified. Permanent static dissipative worksurfaces shall be connected to any SRS in the area served – except to a single point ground system. Permanent ESD protective static dissipative worksurfaces shall have a resistance greater than 1.0×10^6 ohms point-to-point (R_{tt}) and less than 1.0×10^9 ohms (ANSI/ESD S4.1). Permanent ESD protective worksurfaces shall have a resistance from their surface to the groundable point (R_{tg}) greater than 1.0×10^6 ohms and less than 1.0×10^9 ohms (ANSI/ESD S4.1).